Analysis of Adaptive Data Fusion Approaches within LM Canada's Technology Demonstrator

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ABSTRACT

Lockheed Martin Canada (LM Canada) has developed a Technology Demonstration environment, which over the last decade has been used to demonstrate initial proof-of-concept and then analyse various approaches for enhancing overall Data Fusion system performance for applications to Canada's defence programs. It has a blackboard-based architecture that permits mix of rule-based and algorithmic approaches, specifically useful in the implementation of higher-level fusion capabilities. Various aspects of these efforts, such as fusion architectures, algorithms and information sharing strategies between multiple collaborating platforms have been presented previously [1,2].

This paper presents currently on-going efforts towards the analyses of concepts for level 4 fusion, i.e. methods for adapting the fusion processes based on the tactical and environmental factors.

1.0 INTRODUCTION

Over the last 13 years, LM Canada's Research and Development (R&D) department in collaboration with Defence Research and Development Canada (DRDC) has been developing data fusion capabilities in support of Canada's defence programs. The initial efforts started with the development of a data fusion capability that fused Above Water Warfare (AWW) onboard sensor data of the Halifax Class frigate [3]. Then Image Fusion capabilities were added to provide data fusion capability for airborne surveillance [4]. To ensure that data fusion developments aimed at different programs can leverage capabilities developed previously, a common Technology Demonstration environment was established where all data fusion techniques and capabilities are developed, evaluated and demonstrated using the same infrastructure. This Technology Demonstration infrastructure is built based on the distributed blackboard-based knowledge based system architecture (Cortex), developed at LM Canada [5], sponsored by DRDC. The blackboard-based architecture was chosen to support the rule-based, concurrent and ad hoc reasoning requirements of higher level fusion. The distributed nature of this architecture was necessary to be able to support various data fusion architectures in different programs as well as to support multi-platform collaboration in a task force and evolution to Network Centric Warfare (NCW). The data fusion methods, techniques and capabilities are being developed and integrated

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into the Technology Demonstrator (TD) based on the priorities of the various programs that LM Canada becomes involved in, however an overall data fusion model that foresees the evolution into the human-in-the-loop, multi-platform data fusion of levels 1 through 4, supporting NCW has been developed. Currently a Multi-Platform Multi-Source Data Fusion (MP MSDF) – Level 1 Collaborative Data Fusion capabilities have been demonstrated. The TD also contains a subset Situation and Threat Assessment and Resource Management (STA/RM) capability – Level 2, 3 Fusion and RM decision support functionality, which is available on any platform , however which provides decision support for the platform alone (MP STA/RM capabilities are not yet developed). At its current state the TD's MP MSDF includes bearing-only association, track-to-track fusion, backwards data integration, bearing intersect fix management, etc. in an architecture permitting data exchange between collaborating platforms. Currently work is on-going to mature the MP MSDF and add more sophisticated fusion techniques, to incrementally add capabilities and evolve Level 2, 3 Fusion and RM, and to introduce Level 4 Fusion, specifically fusion management, i.e. an adaptive fusion capability.

The objective of this paper is to describe the current developments in fusion management and the envisaged evolution of Level 4 Fusion capabilities. To be able to show the path for the evolution of data fusion capabilities, specifically in the area of Level 4 Fusion, first the LM Canada Data Fusion Model is described below.

2.0 THE DATA FUSION MODEL

The LM Canada's data fusion model that is shown in Figure 1.

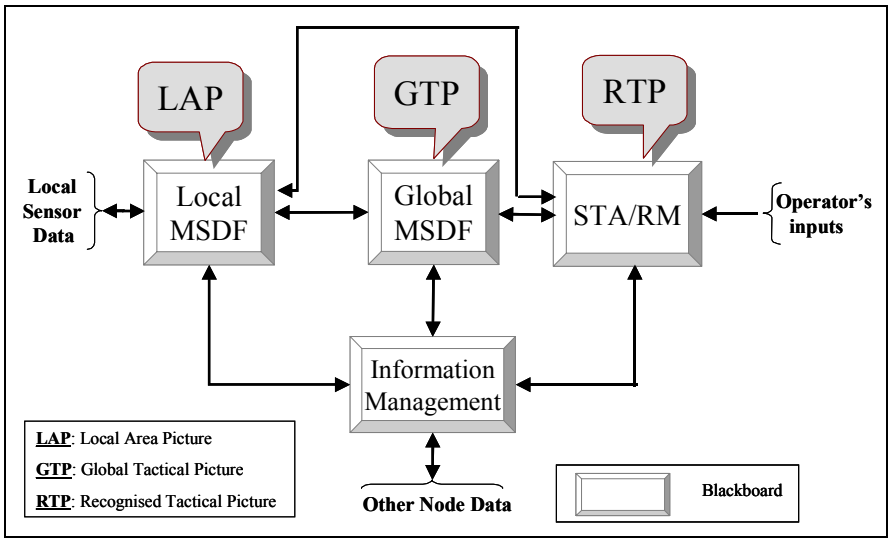

Figure 1: The Data Fusion Model for each Fusion Node on a Network.

This figure shows a set of processes and communication paths between these processes that can exist within a fusion node on a network. Depending on the Data Fusion requirements of a specific defence platform, e.g. naval, airborne, army units, land-based Command and Control Centres, etc., certain processes, and certain communications paths may not be required, or more that one such fusion nodes may be required, however we believe that when building a Data Fusion application it is necessary to examine the requirements for each

process and communication path in this figure. A high level description of the processes and communication links is given below, with specific emphasis on those which play a role in the Level 4 Fusion processing.

2.1 Processes

There are 4 processes:

1) Local MSDF – Level 1 Fusion engine which fuses primary (only I/O to that node) data/information - and generates the Local Area Picture (LAP)

2) Global MSDF – Level 1 Fusion engine which fuses data/information from external (non primary, could be other fusion centres) sources with the LAP and generates the Global Tactical Picture (GTP)

3) STA/RM – Level 2,3, 4, and RM processes that provide decision support for:
   a) The interpretation of LAP and GTP – Level 2 and 3 DF processing,
   b) The MSDF process performance and refinement – Level 4 DF processing
   c) Sensor Management – Level 4 DF processing
   d) Weapons Management – RM processing

   The modifications of GTP based on STA/RM reasoning as well as operator refinements of the GTP are maintained in the Recognised Tactical Picture (RTP).

4) Information Management (IM) – A process that manages the information flow between the Fusion Node and the network

These processes are implemented as blackboards (or set of blackboards) in our TD. Although the Cortex architecture has been mainly developed to satisfy the requirements of STA/RM, all processes in the TD have been developed in Cortex to benefit from its modularity and the facility to perform concurrent development of different components in the system. Furthermore, Cortex permits easy breaking of an application into multiple parallel blackboards, or to combine all processes into one backboard, depending on the specific needs of the application, e.g. processor resource needs or information exchange needs between the processes Overall the analysis of information exchange needs is a very important aspect of the system design. The specific information interchange needs for Level 4 fusion have formed and will form a significant portion of analyses for the establishment of level 4 DF capabilities for the Canadian defence programs, and Cortex will facilitate experimentation with and validation of these capabilities.

2.2 Communication Links

The high level description of information interchange in the various communication links supporting the Level 4 DF processing are:

1) LAP estimates are made available to STA/RM for evaluation of Local MSDF performance

2) STA/RM recommendations are sent to Local MSDF to perform a number of actions to enhance Local MSDF performance including:
   a) Select an alternate association mechanism for a subset of observed targets
   b) Select an alternate filtering approach for a subset of observed targets

c) Modify MSDF parameters for a subset target processing

d) Select different association, filtering, or parametric modifications for data/information coming form a specific source

e) Recommend a Sensor Management action, e.g. provide sensor with target information to support its processing or request information of specific type, location, etc.

3) Local MSDF may also receive requests from other fusion nodes to perform a Sensor Management action through IM

4) GTP estimates are made available to STA/RM for evaluation of Global MSDF Performance

5) STA/RM recommendations are sent to Global MSDF to also enhance the Global MSDF performance. The type of recommendations regarding the Global MSDF algorithms and processing of input data would be the same as for Local MSDF algorithms (bullets a, b, c, d above), while recommendations for processes and information management in external Fusion nodes STA/RM could be send out either via the Global MSDF or directly to IM.

6) IM may also provide Global MSDF with recommendation from other fusion nodes about fusion processing performance (e.g. track quality issues, track number or ID conflicts can lead to changes in MSDF algorithm or parameter modifications.

The description of what already exists within LM Canada's technology demonstrator, what is currently being developed and what are the near term plans for developing, analysing and maturing a Level 4 Fusion capability in the context of NCW are described in the sections below.

3.0 THE TECHNOLOGY DEMONSTRATOR CURRENT DESIGN

Figure 2 shows LM Canada's technology demonstrator's current design.

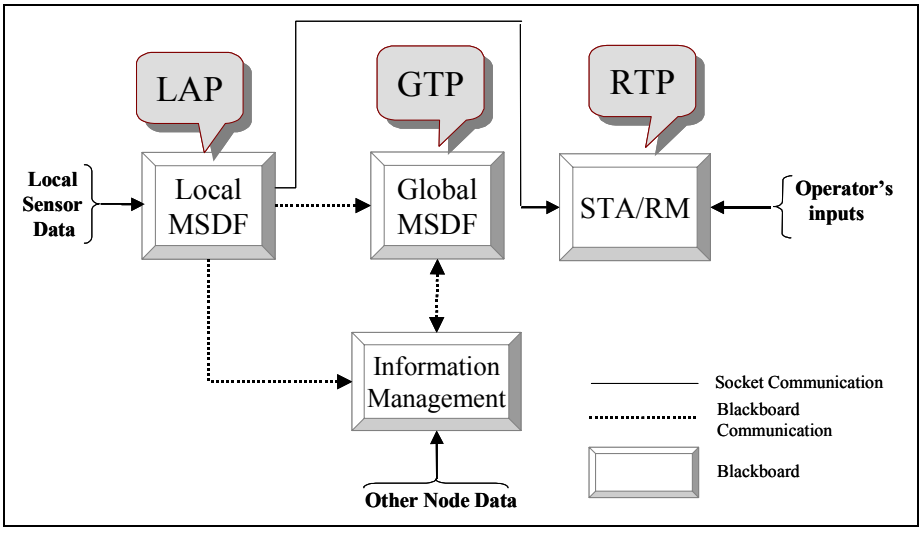

Figure 2: Technology Demonstrator's Current Design.

This design is consistent with the data fusion model described in Figure 1. In Figure 2 communication links are implemented in 2 different ways, through blackboard's intrinsic communications mechanism and through sockets. This design choice is application dependent, determined based on growth and other considerations. For Example in the case of STA/RM a socket communication was used because it is a process that is designed to run as an external process, to be able to integrate also with the company's Naval engineering prototype. The current Level 1 Fusion capabilities (Local and Global MSDF) are relatively mature. STA/RM is currently designed to only perform reasoning regarding the LAP, hence STA/RM has no need to communicate its recommendations on the network. LAP tracks are broadcast on the network for fusion in the Global MSDF of other nodes and GTP tracks can be sent to other nodes using either broadcast or point-to-point link, but the fusion of such data has not yet been fully analysed, in terms of data incest handling.

The current network architecture provides a consistent tactical picture. Each platform maintains parallel track databases. LAP contains the local track estimates produced by the fusion of the measurements created from the local sensor tracks. GTP contains the fused information of the local track databases of the host and remote platforms. RTP contains the reasoning results of the STA decision support tools and the operator inputs regarding the target identification and position refinements. Each one of the high level processes (Local MSDF, Global MSDF, STA/RM and IM) may need to maintain additional layers of information refinements and the blackboard architecture permits to add additional blackboards where the results of different layers of reasoning capabilities regarding the tactical situation are maintained and made available for further analysis if required. The philosophy has been to maintain the reasoning at different levels separate initially primarily to facilitate the handling of data incest issues when fusing data provided by collaborating platforms and in the long run to facilitate the analysis of information interchange requirements between the different reasoning levels. On the other hand the current architecture of the technology demonstrator does not yet support all communication links (information exchange interfaces shown in Figure 1 as well as communication between any additional layers of reasoning) that would be required to analyze this. Based on DND program priorities, these communication links as well as the capabilities in the processes to handle the data that is provided by these links are being implemented incrementally.

The on-going enhancements to the processes and communication links to be able to demonstrate some initial Level 4 Fusion capabilities as well as the on-going experimentation with Level 4 Fusion concepts are described below.

3.1 The On-Going Enhancements

As mentioned above the Level 4 Fusion is responsible for 2 areas:

1) Data Fusion process refinement
2) Sensor/Information source Management

The Level 4 fusion decision support for performing various actions for DF refinement and sensor management are part of (or additional reasoning layer on the) STA/RM process or operator actions.

The current developments are in the area of Data Fusion process refinement, namely which should be the criteria to initiate modification in the data fusion processes, and how to modify MSDF to be able handle processing of different sub-sets of targets using different MSDF methods.

The aspects of the fusion processes that are being considered for refinement currently include:

1) Choice of the association mechanism,

2) Choice of filtering techniques,
3) Modification of parameters within the algorithms for association and filtering.

One can observe from comparison of Figure 1 and Figure 2 that new communication links and processing are required to be implemented to be able to demonstrate and analyse Level 4 Fusion capabilities.

3.1.1 Process Modifications

Addition of new approaches for association and fusion within the fusion centres.

Currently there are 2 methods of association, nearest neighbour (NN) and Jonker Vongenant Castanon (JVC), which are single scan association methods. One multi-scan method, a multi-hypothesis (MH) association has also been added.

Currently there are also 2 methods for filtering, an adaptive Kalman filter and an Interactive Multiple Model (IMM) filter. Both of these filters do not address the data incest issues. Initially, when - mixing of local and global data were not allowed in the position fusion, i.e. local data overwrote global data, if available, these methods were sufficient, however an approach that deals with data incest is necessary, especially when information sharing between fusion centres is recommended by a level 4 fusion decision. Currently 2 types of tracklet fusion approaches have been added for this purpose, however this implies that the covariances are passed between platforms, which is not the case currently in datalink and other communication protocols.

Addition of new STA capability.

As mentioned above STA agents will be incrementally added to detect certain context and criteria that could be considered as basis for decision to modify fusion processes. As a starting point enhancements to the Human Computer Interface (HCI) have been made to be able to interactively input decisions about fusion or sensor management. A capability to select certain targets or sector where the operator can chose modifications to the fusion processes have been demonstrated to be very useful in analyzing Level 4 fusion impact on the overall level 1 fusion performance.

3.1.2 Communication Links Modifications

Addition of communication link between Global MSDF and STA.

A communication link to provide GTP to STA/RM is required and an analysis of information interchange requirements between LAP, GTP and STA to understand the two-way information flow between STA and both Local and Global MSDF is required.

Currently the STA reasoning has been developed mainly to understand the behaviour of some example STA tools and to analyse the human interface requirements for identification refinements for LAP. The impact of STA analyses on the local or global fusion results are only beginning to be a topic of analyses. The results of STA capabilities will provide context and criteria for level 4 fusion. These capabilities applied against either the LAP or GTP would support decision to modify the association and fusion processes of each fusion centre. Similarly STA capabilities can provide decision regarding sensor management for the local database and they can provide decision regarding information interchange between the collaborating platforms. We view this as a longer term research.

Addition of communication link between STA/RM and IM.

This link will permit analysis of information that could be shared between collaborating platforms and modification of interfaces between the platform's databases and the Information Management capability within the platform. As a longer term research, STA functionality will analyse the Global MSDF performance dependence on data from other nodes and recommend fusion modifications in other nodes, or will receive recommendation about the Global MSDF performance from other nodes. This can be classified as Force STA/RM functionality.

4.0 FUTURE PLANS

As in all LM Canada developments work priorities are dictated by the Canadian program priorities. The implementations done and on-going so far are specific bottom-up developments to demonstrate specific capabilities necessary in the current projects. In parallel top-down design activities are on going to analyse:

1) Data exchange requirements in each communication link
2) STA algorithms and heuristics to be used in decision support for adapting the fusion processes. The various context and criteria that could be considered as basis for decision to modify fusion processes include the mission, source reporting the target, the target density, identification, behaviour, geolocation, operator selection, etc. STA capabilities will be developed which will analyse both LAP and GTP based on the various criteria and recommend modifications in the Local and Global MSDF processes.
3) Metrics to quantify MSDF performance at run-time.
4) MSDF architecture and new algorithms in both Local and Global MSDF centres to deal with multiple fusion approaches being used to fuse different subsets of input information/data.

It is clear that the design to be developed here will continuously evolve, therefore the currently chosen system architecture based on Cortex and well documented and enforced message interchange standards. These will ensure that the evolution occurs with minimal re-work.

In the near term rule-based and algorithmic approaches are foreseen to select an alternate association or fusion mechanisms. Then an adaptive fusion approach under development at DRDC Valcartier, which proposes to modify parameters in MSDF based on some criteria, will be analyzed for integration.

Sensor/information source management capabilities can also be incrementally added. For example one of the most obvious cases of such an action is the detection of an ID conflict between the LAP and remote report. A number of sensor/Information source analyses can be initiated and the decision support can range from performing an IFF interrogation, activating an imaging sensor (if available), re-examining the local MSDF ID estimation and instructing a Participating Unit (PU) to do such actions.

5.0 CONCLUSIONS

LM Canada's Technology Demonstrator environment for the incremental development, analysis and demonstration of level 1 through 4 data fusion capabilities for Canada's defence programs was described. The path for specifically building Level 4 Fusion capability and currently on-going analyses and implementations was also shown. However it is understood that the problem of developing the appropriate level 1,2,3 and 4 fusion

capabilities for a system, and especially a network of collaborating systems is extremely large. LM Canada's technology demonstrator has been used to incrementally add, analyse and demonstrate capabilities towards this goal and once some capability has been sufficiently investigated, it is prototyped and demonstrated on-board the Halifax Class frigates.

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MILITARY DATA AND INFORMATION FUSION

PRAGUE, Czech Republic, 20-22 October 2003

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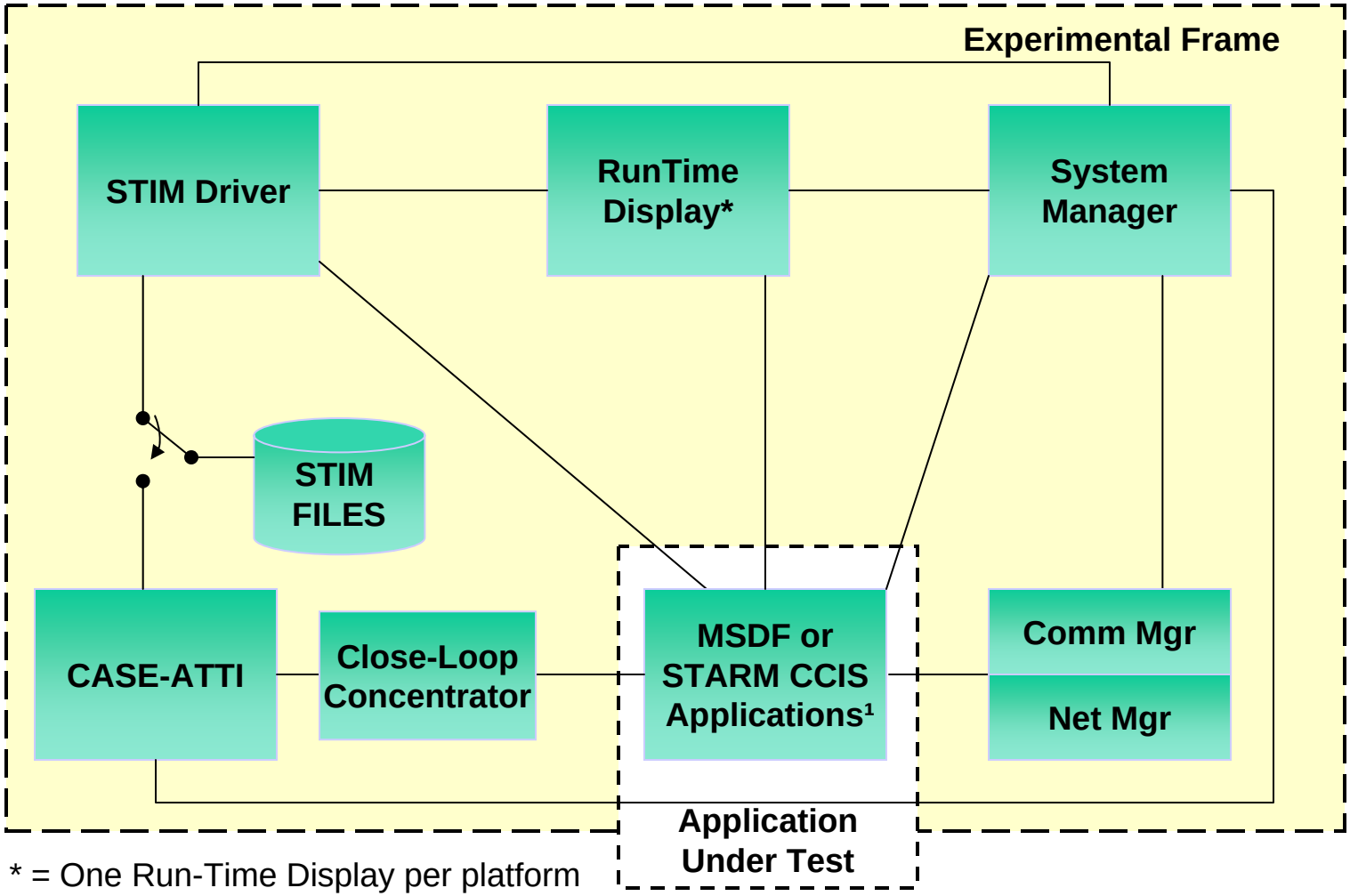
LOCKHEED MARTIN

Introduction

- ***Over the last 13 years, LM Canada's R&D department has been developing Data Fusion capabilities in collaboration DRDC and DND***
- ***LM Canada chose incremental development of a data fusion system based on capabilities and priorities required in programs***
- ***LM Canada chose a modular infrastructure for the Technology Demonstrator (TD) that permits new developments with minimal impact on the existing capabilities***
- ***Currently TD demonstrates distributed data fusion between multiple collaborating Naval and Airborne platforms***
  - ***Mature multi-platform track-level AWW MSDF (Level 1 Fusion)***
  - ***Proof-of-concept single platform STA/RM elements (Levels 2, 3, 4 Fusion and RM)***
- ***This paper describes the current developments in fusion management and the envisaged evolution of Level 4 Fusion capabilities***

LM Canada TD Environment



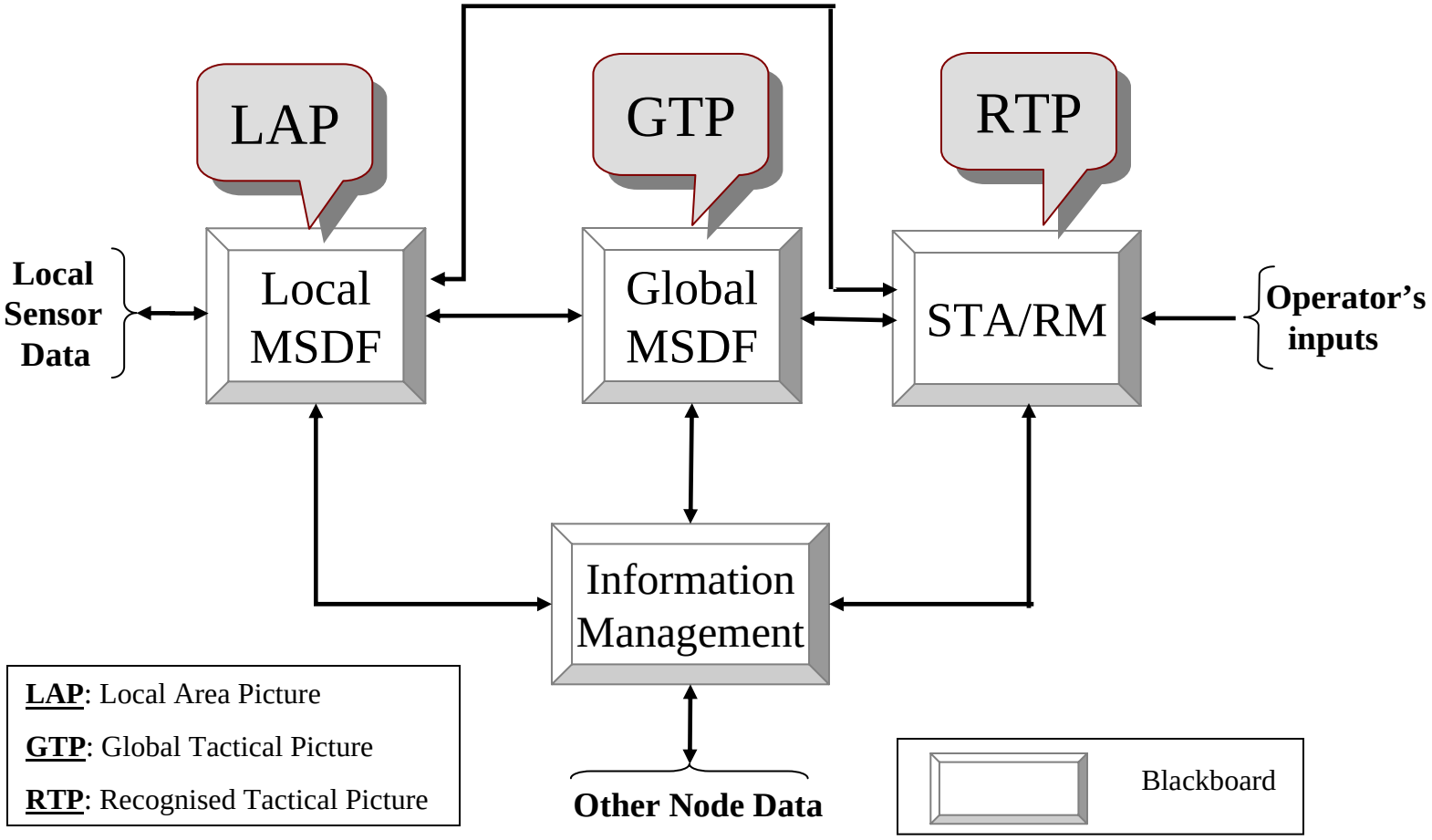
* = One Run-Time Display per platform
¹ = One connection per platform to the Net / Comm Manager

The LM Canada TD Components

The LM Canada TD is a versatile tool used for investigations on data fusion algorithms and to perform data analysis. It consists of:

- ***Experimental Frame (EF);***
  - ***Stimulator (the STIM Driver application)***
  - ***Two human computer interfaces:***
    - ***System Manager application: to control the simulation and the applications under test***
    - ***RTD application: for observing the application output results***
  - ***Net Manager application***
  - ***Communication Manager Application***
- ***CCIS applications***
  - ***MSDF***
    - ***Multi-Source Data Fusion (Level 1 Fusion) for Above Water Warfare (AWW) data from distributed fusion nodes***
  - ***STA/RM***
    - ***Situation and Threat Assessment (Level 2, 3 Fusion) and Resource Management (Level 4 fusion and Weapons)***

LM Canada Data Fusion Model for Communicating Nodes



Multi-Platform Data Fusion Model

- ***In transitioning from single platform to multiple collaborating platforms new components are introduced in LM Canada's Data Fusion Model***
- ***Level 1 Fusion to handle Data Looping and Pedigree***
  - ***Local MSDF fusing information sources of the platform***
  - ***Global MSDF fusing information from other platforms with Local MSDF results***
- ***Levels 2, 3 and 4 Fusion could deal with Local and Global MSDF differently (future analysis)***
- ***Network Management***
- ***Communications Management***
  - ***Information Management is the component of Communications Management that is resident on the platform***

LM Canada Data Fusion Model, cont'd

- ***The DF Model consists of a set of processes and communication paths between these processes internal and external to a node on the network***
- ***Depending on the DF requirements of a specific application, e.g. naval, airborne, army units, land-based CCS, etc., certain processes, and certain communications paths may not be required, or more that one fusion process of a specific type may be required***
- ***We believe that when building a DF application it is necessary to examine/study the requirements for each process and communication path***
- ***We also foresee adding processing and communication paths as the tactical requirements evolve***

Processes

- ***Local MSDF – Level 1 Fusion engine which fuses primary (only I/O to that node) data/information - and generates the Local Area Picture (LAP)***
- ***Global MSDF – Level 1 Fusion engine which fuses data/information from external (non primary, could be other fusion centres) sources with the LAP and generates the Global Tactical Picture (GTP)***
- ***Information Management (IM) – A process that manages the information flow between the Fusion Node and the network***

Processes, cont'd

- ***STA/RM and the Operators jointly assess, interpret, refine the GTP storing information in Recognised Tactical Picture (RTP)***
- ***STA/RM – Level 2,3, 4, and RM processes that provide decision support for:***
  - ***The interpretation of LAP and GTP – Level 2 and 3 DF processing***
  - ***The Local and Global MSDF process performance and refinement – Level 4 DF processing***
  - ***Sensor Management – Level 4 DF processing***
  - ***Weapons Management – RM processing***

Interfaces

- ***Many of the interfaces between the processes in a platform and between distributed platforms are not yet studied***
- ***We believe that many of these interfaces and the processing to deal with the information exchanged can and should be topics of research studies***
- ***Interfaces and processing that currently are implemented will evolve in time***
- ***Examples of information exchange between processes and the platforms follow***

Local MSDF Interfaces

- ***LAP estimates are made available to:***
  - ***Global MSDF to fuse with data/information from other nodes forming the GTP***
  - ***STA/RM perform STA/RM functions and for evaluation of Local MSDF performance***
  - ***IM to provide the node LAP and sensor raw data to other nodes in the network***
- ***Local MSDF may receive input from:***
  - ***Global MSDF for algorithm and sensor cueing***
  - ***STA/RM as refinements to the LAP estimates or as sensor management or process refinement recommendations***
  - ***IM as contact-level data from other nodes (e.g. CEC)? or sensor management or process management requests from other nodes***

Process Refinement Interface Specifics for Local MSDF

- ***STA/RM recommendations are sent to Local MSDF to perform a number of actions to enhance Local MSDF performance including:***
  a. ***Select an alternate association mechanism for a subset of observed targets***
  b. ***Select an alternate filtering approach for a subset of observed targets***
  c. ***Modify MSDF parameters for a subset target processing***
  d. ***Select different association, filtering, or parametric modifications for data/information coming form a specific source***
  e. ***Recommend a Sensor Management action, e.g. provide sensor with target information to support its processing or request information of specific type, location, etc.***
- ***IM may send to Local MSDF process refinement requests from other nodes***

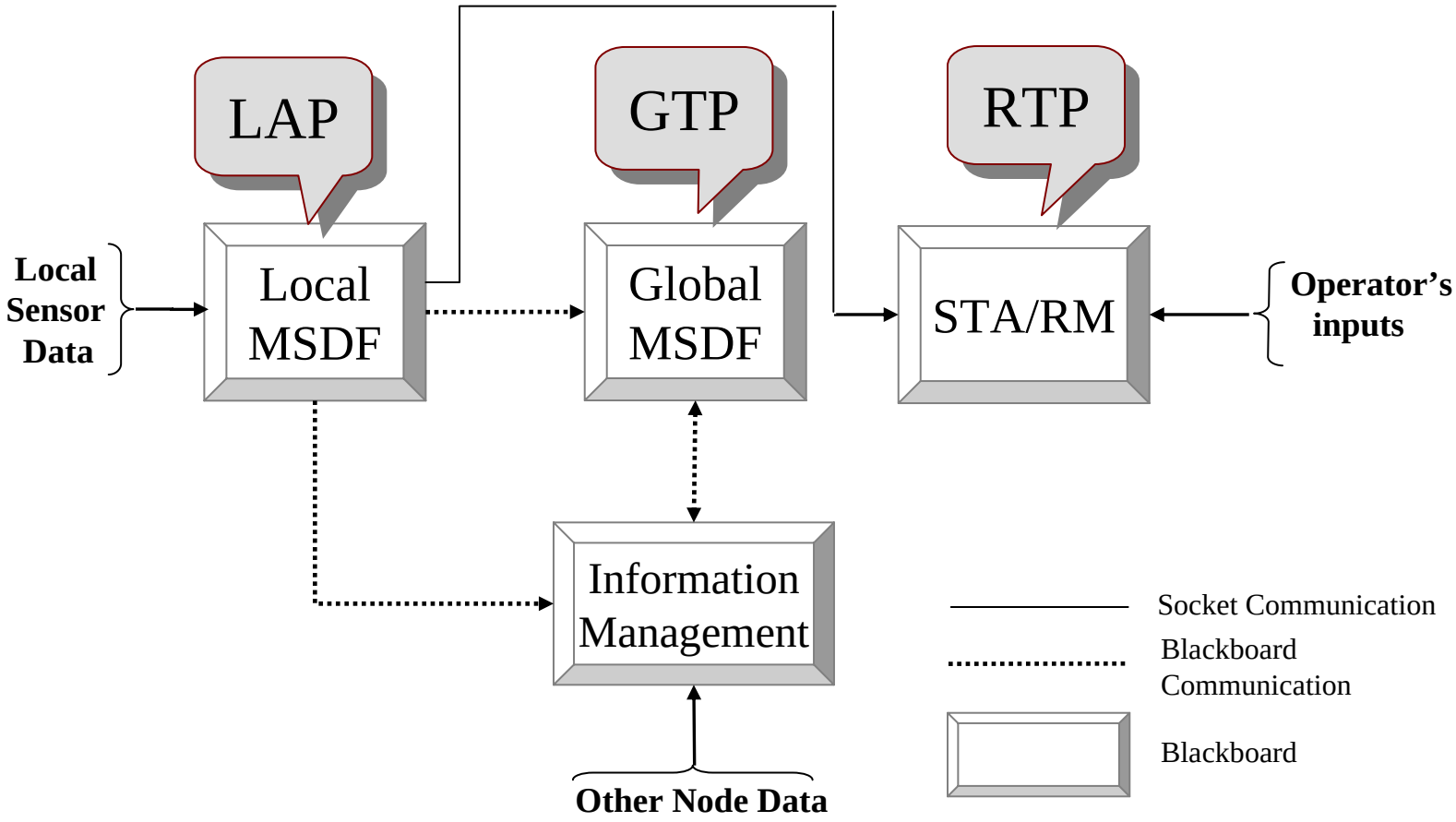
Global MSDF Interfaces

- ***GTP estimates are made available to:***
  - ***Local MSDF for algorithm and sensor cueing***
  - ***STA/RM to perform STA/RM functions and for evaluation of Global MSDF performance***
  - ***IM to provide the node GTP to other nodes in the network***
- ***Global MSDF may receive input from:***
  - ***Local MSDF to be fused with data/information from other nodes***
  - ***STA/RM as refinements to the GTP estimates or as process refinement recommendations***
  - ***IM as track data from other nodes or process management requests from other nodes***

Process Refinement Interface Specifics for Global MSDF

- ***STA/RM recommendations are sent to Global MSDF to enhance the Global MSDF performance***
  - ***Same actions as for Local MSDF algorithms enhancements (a - association, b - tracking, c - parametric, d - sensor data specific, e - sensor management)***
- ***IM may provide Global MSDF process refinement requests from other fusion nodes (e.g. track quality issues, track number or ID conflicts can lead to changes in MSDF algorithm or parameter modifications)***
- ***STA/RM could also make recommendations for processes (specifically Global MSDF) and information management in external fusion nodes.***

Current Data Fusion Implementation



Current Data Fusion Implementation, cont'd

- ***This design is consistent with the data fusion model***
- ***A subset Interfaces have been implemented supporting Level 1 fusion and subset Local STA/RM***
- ***The current Level 1 Fusion capabilities (Local and Global MSDF) are relatively mature for a Naval or Air AWW application***
- ***STA/RM currently consists of a sub-set reasoning agents only for the LAP, hence the current STA/RM does not communicate its recommendations on the network***
- ***LAP tracks are broadcast on the network for fusion in the Global MSDF of other nodes***
- ***GTP tracks can be sent to other nodes using either broadcast or point-to-point link, but the fusion of such data has not yet been fully analysed, in terms of data looping***

Current STA/RM Functions

- ***Situation and Threat Assessment (STA)***
  - ***HALIFAX Class-like Threat Ranking***
  - ***ID Refinement Through:***
    - ***Clustering***
    - ***Rule based allegiance***
    - ***Commercial corridor correlation***
    - ***Manoeuvring target detection***
    - ***Track splitting detection***
    - ***Fast incoming target criterion***
    - ***Ownship Missile recognition***
    - ***Mean Line of Advance***
- ***Resource Management (RM)***
  - ***HALIFAX Class-like Reactive Planning:***
    - ***Point of Intercept***
    - ***Point of first fire***
    - ***Target Weapon Pairing***
    - ***Weapon Designation***
    - ***Resource Allocation***
  - ***Deliberative Planning:***
    - ***Decision tree (plan) creation***
    - ***Plan evaluation/ optimization***
    - ***Plan repair***

On-Going Enhancement for Level 4 Fusion

- ***Level 4 fusion decision support for DF refinement and sensor management requests can be made automatically by the STA/RM process or operator actions***
- ***Currently Operator requests on DF algorithm refinements have been demonstrated***
  - ***Choice of the association mechanism***
  - ***Choice of filtering techniques***
- ***Work is on-going to add processing in Local and Global MSDF and STA/RM, and establish the required interface links between the processes***

Process Modifications

- ***Local and Global MSDF Processes***
  - ***Adding new approaches for association and fusion***
  - ***Adding ability to modify approaches or parameters in real-time for subset targets***
- ***STA/RM Process***
  - ***Enhancements to the Human Computer Interface (HCI) have been made to be able to interactively input decisions about fusion or sensor management***
  - ***A capability to select certain targets or sector where the operator can chose modifications to the fusion processes have been demonstrated to be very useful in analyzing Level 4 fusion impact on the overall Level 1 fusion performance***
  - ***Research in Level 4 fusion approaches to detect certain context and criteria that could be considered as basis for decision to modify fusion processes have been initiated***

Interface Modifications

- ***Addition of tow-way communication link between Local and Global MSDF and STA/RM***
  - ***To study STA/RM requirements for analysing the GTP***
  - ***To study the two-way information flow between STA/RM and both Local and Global MSDF***
- ***Addition of communication link between STA/RM and IM***
  - ***To study of high level fusion reasoning information that could be shared between collaborating platforms***
  - ***As a longer term research to analyse the Global MSDF performance dependence on data from other nodes and to recommend fusion modifications in other nodes, or receive recommendation about the Global MSDF performance from other nodes***

Conclusion

- ***LM Canada's Technology Demonstrator environment for the incremental development, analysis and demonstration of level 1 through 4 data fusion capabilities for Canada's defence programs was described***
- ***The path for specifically building Level 4 Fusion capability and currently on-going analyses and implementations was also shown***
- ***It is understood that the problem of developing the appropriate level 1,2,3 and 4 fusion capabilities for a system, and especially a network of collaborating systems is extremely large***
- ***LM Canada's technology demonstrator has been used to incrementally add, analyse and demonstrate capabilities towards this goal***
- ***Once some capability has been sufficiently investigated, it is prototyped and demonstrated on-board the Halifax Class frigates***